ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY (AASTU)

COLLEGE OF ARCHITECTURE AND CIVIL ENGINEERING

Alternative structural system for low cost housing projects

Independent Project submitted to the school of graduate studies of Addis Ababa Science and Technology University in partial fulfilment of the requirements for the degree of Master of Engineering in Civil Engineering

By : Kelbishe Chomen Kajela

June 2017

ALTERNATIVE STRUCTURAL SYSTEM FOR LOW COST HOUSING PROJECTS

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APPROVAL PAGE

This **Meng Project** entitled with **"Alternative Structural System for low Cost Housing Projects** "has been approved by the following examiners in partial fulfillment of the requirement for the degree of **Master of Engineering** in **Structural Engineering**.

Date of Defense: May 26, 2017 G.C

Principal Advisor

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Signature Date

Members of the Examining board:

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And Civil Engineering

DECLARATION

I, the undersigned declare that this project entitled **Alternative structural system for low cost housing projects** is my original work, and it has not been presented for a degree in Addis Ababa Science and Technology University (AASTU) or in any other University and that all source of materials and references used for the project have been fully acknowledged.

Kelbishe Chomen Kajela Signature………………….Date…………………

ACKNOWLEDGEMENT

First of all I would like to thank the almighty God from the bottom of my heart for His never ending gift and His provision to complete this work.

I would like to express my sincere appreciation to my brother Naol Imiru for his advice in the commencement of the study and valuable suggestions, encouragement and guidance of my project work. Furthermore, he has devoted his time and energy to advise me during the whole work and recommended valuable comments to improve the project.

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ABSTRACT

The project explores the potential of steel structural frame as an alternative building material for low cost housing. The rational for the application of steel comes from its abundance Industries now a day in Ethiopia, and its proven physical properties that equate it to other building material like concrete. The proposed steel and pre-stressed hollow core slab based design solution concentrates on simplification of construction methods, the need to provide clear floor spans for more usable space, speed of construction, prefabrication of structural components and cost of construction time. To complete the design of G+4, Type B concrete and steel structure system, the 3D Model of the frame is analyzed using ETABS16 Ultimate 16.00 software. Finally, the cost comparison of the two systems is carried out based on economy, and management and efficiency. From the comparison, some conclusion and recommendation are forwarded.

Key words: Steel, Concrete, Low cost housing, Pre-stressed hollow core slab, ETABS16 Ultimate 16.00

LIST OF SYMBOLS

Latin upper case letters

Aa = Cross-sectional area of structural steel

Ac = Cross-sectional area of concrete

Ag = Total cross-sectional area

As = Cross-sectional area of reinforcement

Av = The shear area

A's = Area of reinforcements within the region of the steel web.

C_1 = Coefficient as a function of moment distribution

Ea = Design value of modulus of elasticity of structural steel

Ecd = Design value of modulus of elasticity of concrete

Ecm = Secant modulus of elasticity of concrete

EI = Flexural rigidity (per unit width for slabs)

Es = Design value of modulus of elasticity of reinforcing steel

Fa = Tensile force in the structural steel necessary to resist the design Hogging bending Moment M calculated from plastic theory.

Fs = Tensile force in the Reinforcement necessary to resist the design Hogging bending Moment M calculated from plastic theory

Fc = Compressive force in the concrete flange necessary to resist the design sagging bending

I = Second moment of area of the total cross-section.

Mb,Rd = The design buckling resistance moment of a laterally unrestrained beam

Mpl, Rd = Plastic Moment Resistance of the Steel Section

Msd = Design bending moment

Ncr = Critical Buckling load

P,Rd = Plastic resistance to compression

Wpan = Plastic section moduli for the structural steel.

Latin lower case letters

a = Location of reinforcement from top surface of upper flange

b = Width of flange of the steel member

beff = Effective width of concrete slab

e = Eccentricity of the loading

fcd = Design value of concrete compressive strength

fck = Characteristic compressive cylinder strength of concrete at the age of 28 days

fy Nominal tensile yield strength of structural steel, Yield strength 'of the structural steel

fyd = Design yield strength of reinforcement

fyk = Characteristic yield strength of reinforcement

h = Depth of web of tha steel member

hc = Total Cross section depth of concrete

twc = Thickness of web column

tfc = Thickness of flange column

Greek lower case letters

βw = Partial safety factor for structural steel

γf = partial safety factor for load

γm = partial safety factor for material strength

γc = partial safety factor for concrete

γs = partial safety factor for reinforcing steel

$\lambda =$ Slenderness ratio.

ϕ = Diameter of the reinforcing bar

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1. INTRODUCTION

1.1. Back ground

The shortage of housing is among the most visible problems of poverty in Addis Ababa. Due to this problem currently Low-Cost house constructions are spreading over different areas around Addis Ababa. The aim of this low cost house project is to alleviate the housing problem with affordable price, to create job opportunities and to promote small and medium-sized construction companies' ***(UN-HABITAT**, **2010)***. Even if many low cost housing is built the demand is not satisfied yet. In order to overcome the demand and cost efficient and speed of construction is important.

Cost efficiency is one of the most crucial points of low cost housing. It is achieved by standardization of building elements and reducing the number of different items needed. Prefabrication and the use of machines and special tools to produce these standardized elements maximize productivity resulting in lower cost per unit. The new technologies that are introduced and used in current low-cost housing constructions are u-shaped block, reinforcement for column inside, combined strip-and slab foundation and pre-fabricated slab system (beams and hollow blocks), (***Ministry of Federal Affairs, 2003)***.

Structurally currently used reinforced concrete frame and precast slab structures are time consuming, ***(Abebe shawel**, **2008)***. The use of steel structures in buildings has much advantage because it is fast to erect and construction is lightweight, particularly in comparison with traditional concrete construction. The aim of this paper is to improve current reinforced concrete structural system by steel structure and also precast slab by pre-stressed hollow floor units.

1.2. Statement of problem

At present day the costs of condominium houses are increasing at alarming rate especially that of the cost of concrete is currently very high as compared to its cost that was even a year ago. So, as known that the steel structures are light weighted and they are super-quick to build at site, as a lot of work can be pre-fibbed at the factory. A wide range of ready-made structural sections are available, such as me, C, and angle sections, (Eurocode Development (2001)

For existing low cost housing, Mat foundation and footing are commonly used depending on the type of soil condition and building type and, for Mat foundation there is large volume of bulk excavation, concrete and reinforcement work. But, steel structures are comparatively light which reduces the weight by 60% of concrete frame structures ***(Eurocode Development (2001)***.
This makes the foundation system to be economical and easy; we can also use simple isolated pad foundation for good soil condition or pile foundation for loose soils, **(Bowles, Mc-Gram Hill).**
The slab system of current condominium houses may faces different problem such as: relatively inconvenient floor system, Leakage problem, the Hollow blocks may fall down and relatively it is not sound (Sound interruption between floors). But, pre-stressed hollow core slab is a precast pre-stressed concrete member with continuous voids provided to reduce weight and, therefore, cost and, as a side benefit, to use for concealed electrical or mechanical runs, ***(Abebe shawel, 2008).*** This system of construction does not require form work and Propping during installation. These kinds of floors have roughly a self weight equal to half of a solid section of the same depth ***(Kim S, 2002)***.

Thus, it is important to propose new structural system for current low cost housing since quality control, time saving and reliability have become the motto of civil engineering.

1.3. Objectives of the project

Main objective of this project is:

- ✓ The aim of this project is to improve current reinforced concrete structural system by steel structure and also precast slab by pre-stressed hollow floor units.
- ✓ Propose new architectural layout for G+4 low cost housing for concrete and steel structures
- ✓ Design of steel structural system for proposed building
- ✓ State the advantage of steel structure and its drawback with its remedies
- ✓ Changing existing precast slab system with hollow core slab
- ✓ Comparison of structural system in terms of cost for concrete and steel

2. EXISTING STRUCTURAL SYSTEM

2.1. Introduction about the system

A beam and block slab is composed of rectangular shaped (generally) precast concrete reinforced ribs supporting rebated filler blocks placed between two ribs ***(Birhanu Adane and Mesfin T, 2012)***. In-situ concrete is poured between and over the blocks. The beam and block slab system is more flexible in coping with irregular shapes. Spans are smaller and the lifting capacity required to place beams is less. It is significantly slower than hollow core slab in construction time as in-situ concrete must be poured and cured. Propping of the system during construction is required with a beam and block system. Precast beam elements are prefabricated reinforced concrete members having sufficient strength to carry shear and flexure. The lower portion of the reinforcement is precast, while the upper portion is exposed and yet to be casted with in-situ concrete after they are laid with hollow concrete blocks (***Eurocode Development 2001)***.

2.2. Advantages

Some of the detailed advantages of precast beam and block slab system are

- ✓ Precast slabs can be erected a lot quicker than in-situ slabs.
- ✓ Eliminating the requirement for crane erection
- ✓ Reduced erection time and labor cost over conventional reinforced concrete slabs
- ✓ Excellent structural integrity (monolithic slab)
- ✓ They are ideal for soffit plaster but fixing of suspended ceilings are also easy and simple
- ✓ Non-highly skilled labor required for installation, rather needs non skilled labors
- ✓ Relatively Lightweight structure

2.3. Draw backs

- ✓ **Time taking**

Precast beam and hollow block Slab installation requires no mechanical aids and is manually installed using a number of skilled and non-skilled laborers. Depending on the number of crews are employed slabs can be erected at rate of up to 50 to 100m² per day per floor.

- ✓ **Poor workmanship**

As most of the workers are unskilled there happen many wrong acts unless the supervisors are stick there

- ✓ **Slab system problem**

Relatively it is not the convenient floor system
Leakage problem
The Hollow blocks may fall down
Relatively it is not sound (Sound interruption between floors)

- ✓ **Foundation system**

Mat foundation and footing are commonly used depending on type of soil condition and building type. For mat foundation there is large volume of bulk excavation, concrete and reinforcement work.

3. NEW PROPOSED SYSTEM

3.1. Introducing about the system

In multi-story buildings , the design of the primary structure is strongly influenced by many issues, as defined below:

- Speed of construction, which may influence the number of components that are used and the installation process.
- The need to provide clear floor spans for more usable space
- Sufficient living area and
- The choice of cladding system
- Planning requirements, which may limit the building height and the maximum floor-to-floor zone
- The services strategy and effective integration of building services
- Site conditions, which dictate the foundation system and location of foundations

With this respect steel frame structures are best suit, hence I have proposed steel frame structures with pre-stressed hollow core slabs.

3.2. Advantage of steel structure

Steel structures have the following advantages**:**

- ✓ **Speed**

They are super-quick to build at site, as a lot of work can be pre-fabbed at the factory. A wide range of ready-made structural sections are available, such as I, C, and angle sections

- ✓ **Flexibility**

They are flexible, which makes them very good at resisting dynamic (changing) forces such as wind or earthquake forces. They can be made to take any kind of shape, and clad with any type of material.

- ✓ **Reduced foundation load**

Reduced self-weight, steel structures are comparatively light which reduces the weight by 60% of concrete frame structures. This makes the foundation system to be easy we can use simple isolated pad foundation for good soil condition or pile foundation for loose soils.

- ✓ **Reduced disruption to the locality**

As most systems are produced in factory system it has very low disruption to the locality.

- ✓ **Easy joint systems**

A wide range of joining methods is available, such as bolting, welding, and riveting

3.3. Draw backs

Steel Frame structures have the following draw backs:

- ✓ They lose strength at high temperatures, and are susceptible to fire,

  Measure-can be reduced by coating the frame structure by insulated materials

- ✓ They are prone to corrosion in humid or marine environments.

  Measure- Our countries' environmental system is not marine and humid.

- ✓ Comparatively costly

  Measure- it is compensated by simple foundation system and fast speed construction

- ✓ Needs Modern Technology

Measure taken- As the housing problem in Addis is critical, the government can train professional personnel's and provide construction equipment's in bulk

4. METHODOLOGY

This project is will primarily computer based structural analysis ETABS 2016 Ultimate 16.00 and use of EBCS-3 Final Draft(Ethiopian Building Code Standards) since the project objectives are aimed to improve current reinforced concrete structural system by steel structure and also precast slab by pre-stressed hollow floor units.

The summarized methods for this project are as follows:-

- ✓ Reviewing different literatures.
- ✓ Propose new Architectural lay out and preliminary plan, for concrete and steel structural system and quantifying its component materials for frames of the building.
- ✓ Structural Modeling and plan for concrete frames with different column spacing and quantifying its frames for comparison purpose.
- ✓ Structural analysis and design of steel frames with different column spacing and quantifying its frames
- ✓ Connection practice and design for both steel and hollow core concrete floors with beams and walls.
- ✓ Comparison and structural evaluation of the two systems.

5. PRELIMINARY ARCHITECTURAL DESIGN

5.1. Design Considerations

In this proposal, priority is given to achieving the maximum efficiency and simplicity of style. The volumetric composition as well as the façade treatment employs simple rectangular volumes and shapes. This not only gives the building clarity of expression, but also translates into simplicity and ease of construction.

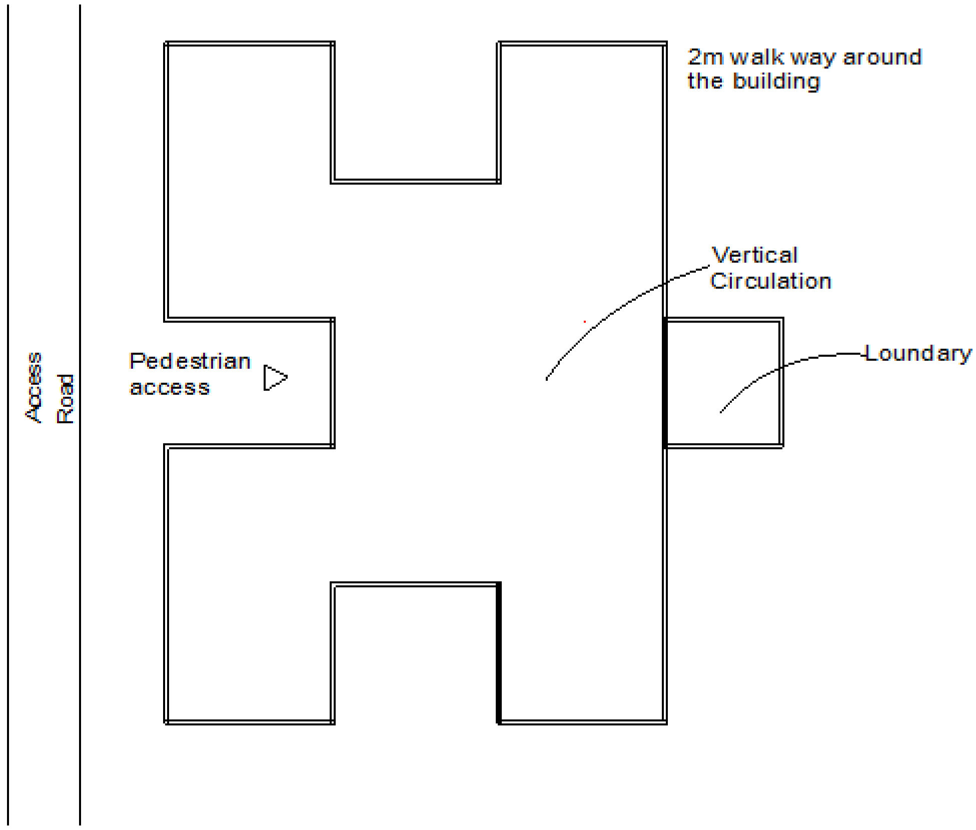

Figure 1 Archetectural Lay out.

Due attention is also given to the use of natural light and ventilation. That is way interlocked rectangular shapes are used.

5.1.1. Site utilization

The site has a shape close to a rectangle of 21.8 meters width and 35.6 meters depth. In this proposal, I have attempted highly efficient land utilization by taking up the maximum allowable area for building which is 625 m^2.

5.1.2. Client's requirement

Following the client's requirement Studio, one bed, two-bed room and three bed room are included in each floor.Additionaly,laundary facility are provided in each floor.

5.1.3. Program of Accommodations

28 apartments of different sizes varying from $30m^2$ up to $120m^2$ are made available within a conductive neighborhood:

- 28.57 % (No.8) apartments are studio type ($30m^2$ each).
- 28.57% (No.8) apartments are one bed room type ($60m^2$ each).
- 28.57% (No.8) apartments are two bed room types ($90m^2$ each).
- 14.28% (No.4) apartments are three bed room type ($120m^2$ each)
- Laundry, lobby, corridor and stair are $145m^2$ in each floor.

So the total floor are in each floor are $625m^2$

5.1.4. Structural system used

Steel structural system is used because the versatility of steel gives architects the freedom to achieve their most ambitious visions. For the vast majority of buildings the most effective structural steel frame is the one which is least obtrusive. In this way it imposes least constraint on internal planning, and produces maximum usable floor area, particularly for open-plan building. It also provides minimal obstruction to the routing of building services. This is an important consideration, particularly since building services are becoming more extensive and demanding on space and hence on the building framework.

5.1.5. Architectural Preliminary plan

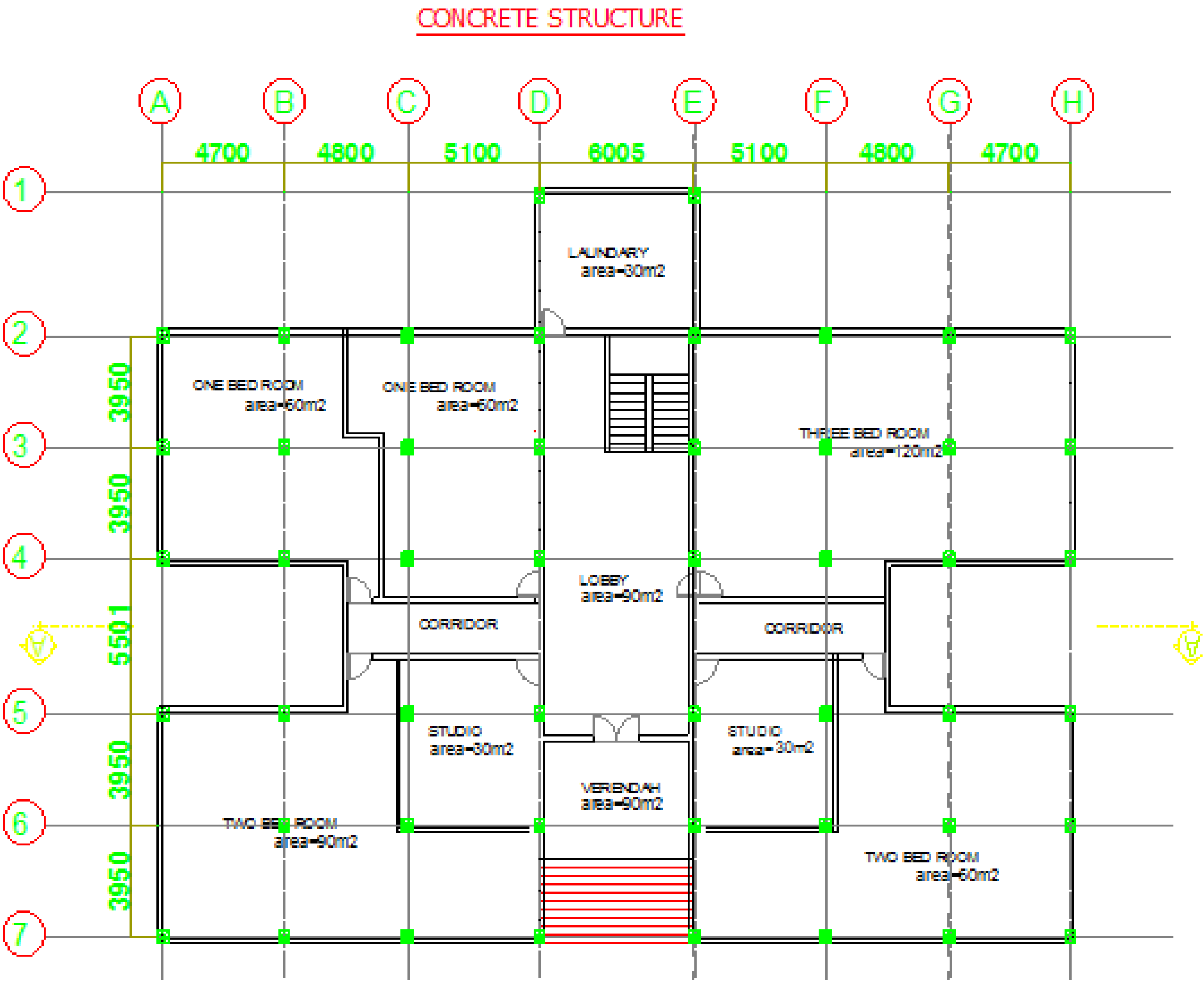

Figure 2 Typical ground to 4th floor plan concrete scale 1:100

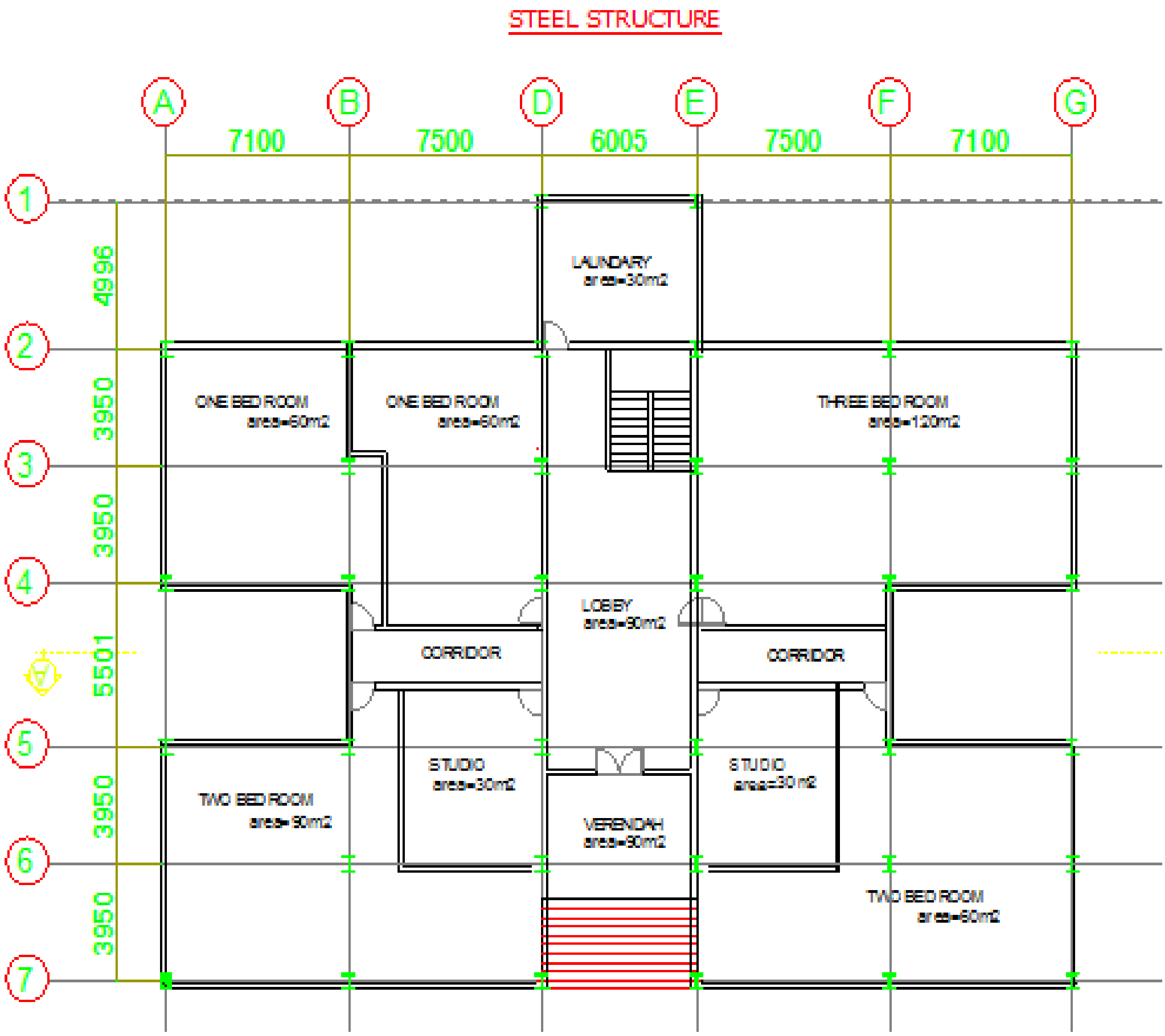

Figure 3 Typical ground to 4th floor plan steel   scale 1:100

6. STRUCTURAL SYSTEMS

6.1. Frame System

Steel Frame Structure

The structural system required for stability is primarily influenced by the building height. For buildings up to eight story height, the steel structure may be designed to provide stability, but for taller buildings, concrete or braced steel cores are more efficient structurally. With this respect my proposed system is four stories hence I choose steel frame.

This immense strength is of great advantage to buildings. The other important feature of steel framing is its flexibility, ***(Design of Steel-Concrete Composite Structures. (2013)****),*. It can bend without cracking, which is another great advantage, as a steel building can flex when it is pushed to one side by say, wind, or an earthquake. The third characteristic of steel is its plasticity or ductility. This means that when subjected to great force; it will not suddenly crack like glass, but slowly bend out of shape. This property allows steel buildings to bend out of shape, or deform, thus giving warning to inhabitants to escape. Failure in steel frames is not sudden - a steel structure rarely collapses. Steel in most cases performs far better in earthquake than most other materials because of these properties.

Columns in multi-story steel frames are generally H sections , predominantly carrying axial load, ***(Design of Steel-Concrete Composite Structures (2013)****)*. When the stability of the structure is provided by cores, or discreet vertical bracing, the beams are generally designed as simply supported. The generally accepted design model is that nominally pinned connections produce nominal moments in the column, calculated by assuming that the beam reaction is 100 mm from the face of the column. If the reactions on the opposite side of the column are equal, there is no net moment. Columns on the perimeter of the structure will have an applied moment, due to the connection being on one side only.

Although small column sections may be preferred for architectural reasons, the practical issues of connections to the floor beams should be considered. It can be difficult and costly to provide connection into the minor axis of a very small column section.

Figure 4 .Structural modeling layout for steel frame

6.2. Structural floor systems

6.1.1. Pre-stressed Hollow Core Floor Slab

A pre-stressed hollow core slab is a precast pre-stressed concrete member with continuous voids provided to reduce weight and, therefore, cost and, as a side benefit, to use for concealed electrical or mechanical runs. This system of construction does not require form work and Propping during installation. These kinds of floors have roughly a self weight equal to half of a solid section of the same depth. Most common depths range from 150 to 300mm and most common widths range from $600 \text{ to } 1200mm$ ***(Abebe shawel, 2008)***

The hollow core slab is manufactured in the quality-controlled conditions of a small to large scale factory and the only site work involved is the placing of a leveling screed 30 to 45mm thick. Hollow core slab fitting into non-modular widths (module normally 600mm, 900mm or 1200mm) are cut to size in the factory while concrete is fresh. They are cut to length to suit as built building dimensions immediately after the concrete has reached the required strength. Propping is usually not required on hollow core slabs and following trades can start work immediately after erection, ***(Abebe shawel, 2008)***.

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Precast, pre-stressed concrete floors offer significant advantages in many types of building construction. They offer design, time and cost advantages over other flooring materials and systems and are suitable for use with all structural systems, i.e. concrete, masonry and steel.

In our country precast pre-stressed concrete elements are not widely used for construction of most buildings. The conventional cast in-situ construction require lots of formwork and construction time, and also the precast beam-slab system construction require propping and construction time too which increases the total cost of a project.

The economy of the generalized hollow core slab system is require a short construction time compared to precast beam slab system and in the quantity of slabs that can be produced at a given time with a minimum of labor required. Each slab on a given casting line will have the same number of pre-stressing strands. Therefore, the greatest production efficiency is obtained by mixing slabs with the same reinforcing requirements from several projects on a single production line.

a) Construction Methodology for Hollow Core Slabs

Hollow core slabs are manufactured to suit the as built dimensions of the building. They are delivered to the site on the day that they are required to be erected onto the building. a crane is required to place the slabs into position directly from the delivery truck and or from the site storage area. Tower cranes give maximum reach but on normal 2, 3 and 4 storey buildings mobile cranes are used. They have a lifting capacity of 30 tones with a 31m boom, and operate easily over a 17m radius. With hollow core slab the placing of $600m^2$ to $700m^2$ of finished floor area per shift can be achieved (**Abebe shawel, 2008**)

b) Advantages of Hollow Core Floor Slab

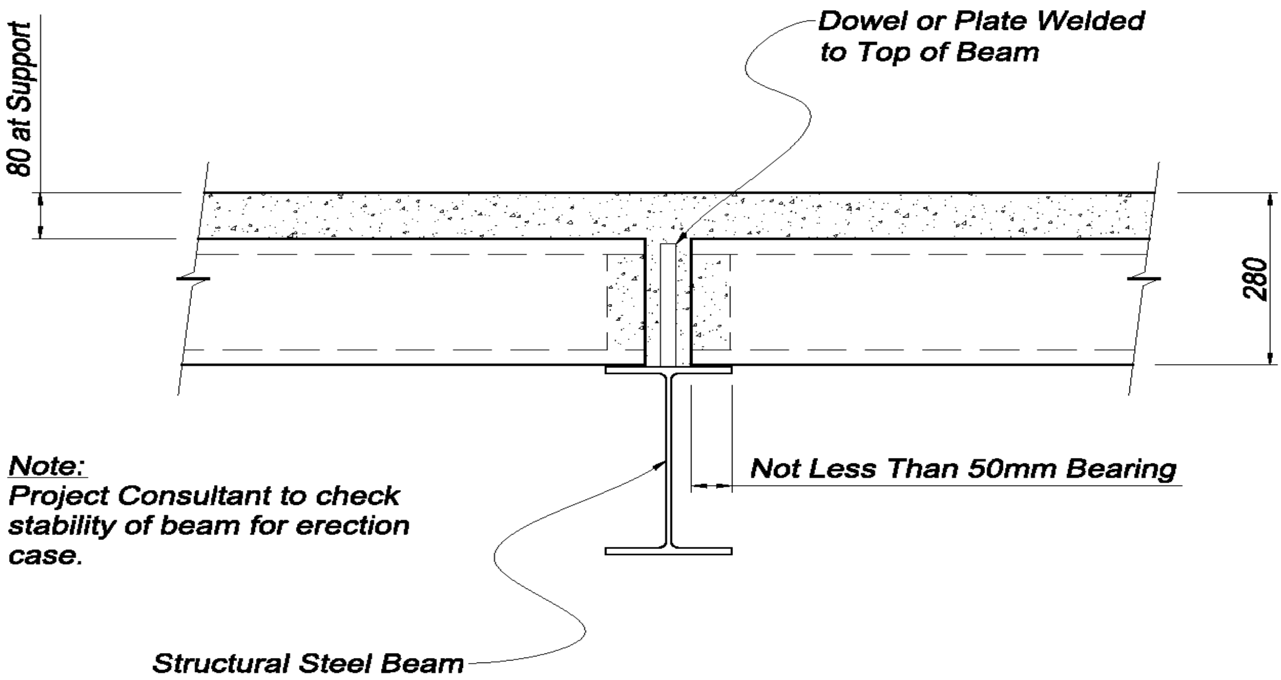
The main advantages of the hollow core floor slab can be summarized as follows:-

- It reduces the total dead load of the building as it provides us a smaller cross sectional dimension, compared with other floor systems
- Speed of erection-Time consuming activities such as propping, shuttering and concrete pouring are virtually eliminated.
- Immediate un-propped working platform-Propping is generally not required with hollow core floors. Once a precast hollow core floor is erected it is immediately available as a working platform.
- Minimum in-situ concrete- a relative large volume of work is carried out off site; this reduces what can be a complex and a time consuming site operation that is subjected to different types of climate conditions.
- Extra long spans-Factory made pre-stressed units offer the maximum design advantages of achieving long span units for a given depth. This avoids the need for intermediate supports.
- Diaphragm action-when structurally grouted; provide a floor with full diaphragm action to the building. A structural concrete topping is not required.
- Structural efficiency-it gives the ideal structural section by reducing the dead weight whilst providing the maximum structural efficiency within the slab depth.
- Factory produced to rigorous quality standards- as it is factory produced; they are manufactured in better quality.
- Voids in a hollow core slab may be used for electrical or mechanical runs

Figure 5 Typical prestressed hollow core concrete floor units (Kim.S, 2002)

c) Connections in Hollow Core Slabs

Connections will be required in hollow core slab systems for a wide variety of reasons. Most connection requirements will be for localized forces ranging from bracing a Partition or beam to hanging a ceiling.



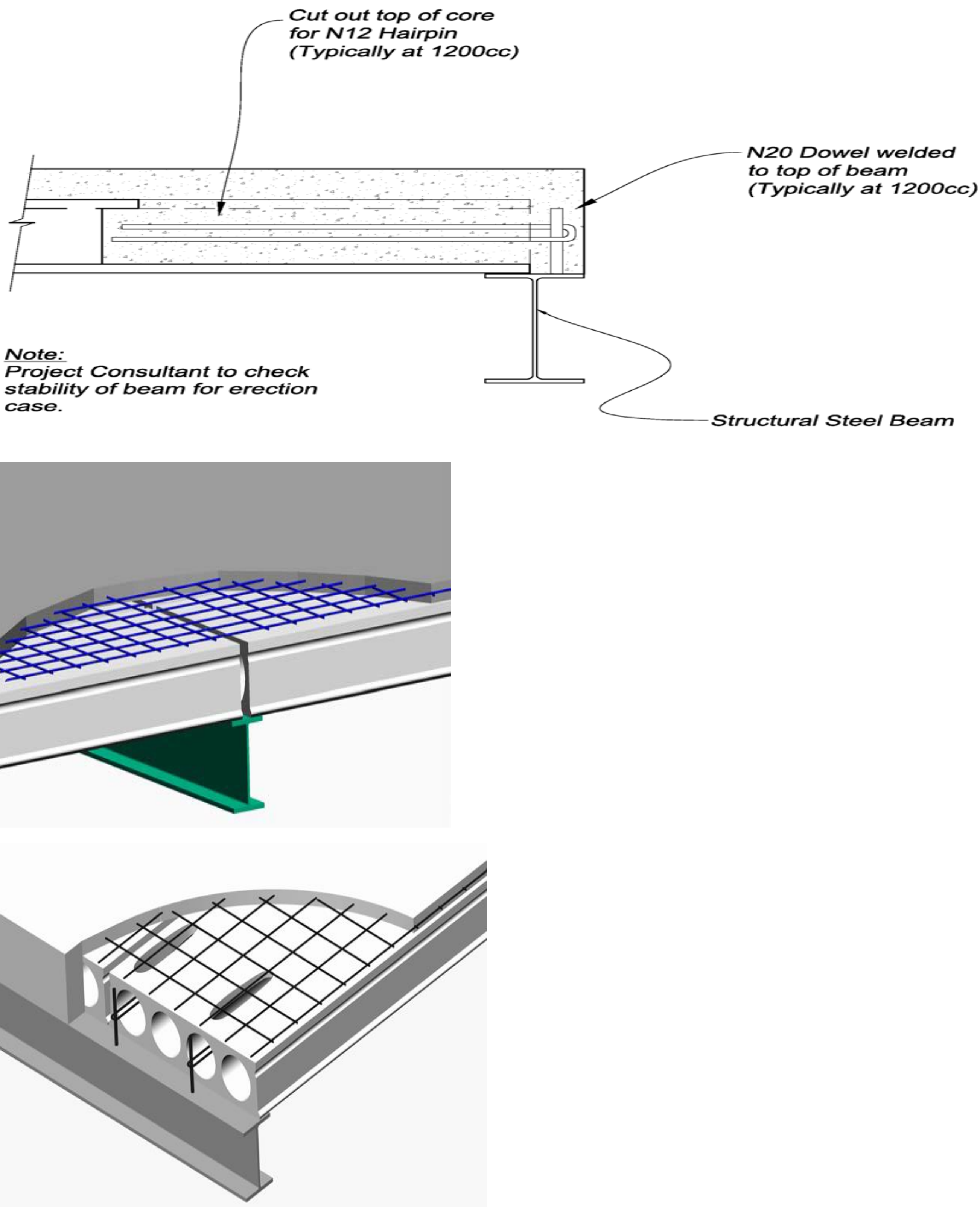


Figure 6 Hollow core conection (Abebe shawel, 2008).

6.3. Foundation System

There are a variety of different foundation options out there and choosing the most suitable one for my needs depends upon a few different variables:

- The stability and layout of the terrain foundation will rest on
- Horizontal forces on your structure, such as wind and rain
- Vertical forces on your structure, such as gravity and building load

Since my structure is light and less complex then it is not necessary to build a full slab (mat foundation), instead several concrete pads when facing good soil conditions or piles if the soil condition is loose will provide enough support and anchor the building, **(Bowles, Mc-Gram Hill)**.

The most obvious site-dependent factors are related to the ground conditions. A steel-framed building is likely to be about 60% of the weight of a comparable reinforced concrete building ***(EurocodeDevelopment (2001)***. This difference will result in smaller foundations with a consequent reduction on costs. In some cases this difference in weight enables simple pad foundations to be used for the steel frame where the equivalent reinforced concrete building would require a more complex and expensive solution.

6.4. Structural design

The structural design for the project was done with the main aim of providing safe and cost efficient housing. The Ethiopian Standard Code of Practice, EBCS-3 Final Draft, provisions are considered.

Additionally ETABS 2016 Ultimate 16.00 are used for analysis, modeling and Designing of structural systems.

<u>Specification</u>

Purpose – Condominium Buildings

Approach- Limit state design method

Material – Concrete – 25, class – I works

Steel S – 300 and S-400 deformed bars

Steel Grade S355

RHS for roof truss and purling

EGA- 300 for roof cover is used.

Partial safety factors – concrete $\gamma_C = 1.5$

Steel $\gamma_S = 1.15$

Steel Grade $\gamma_{mo} = 1$

Unit weight of concrete $\gamma_c = 24KN/m3$

Design Data and Materials

Concrete f_{ck} = 0.8*25MPa =20MPa

f_{ctk} = 0.21*fck2/3 =1.547MPa

f_{cd} = 0.8*5 f_{ck} / γ_c =11.33MPa

f_{ctd} = f_{ctk} / γ_c =1.032MPa

Steel, f_{yk}= 300MPa

f_{cd}= 260.87MPa

Steel Grade, f_y= 355MPa

Design loads

Fd= γf*Fk

Where, Fk = characteristics loads

γf = partial safety factor for loads

= 1.3 for dead loads

= 1.5 for live loads

6.4.1 Design of Columns and Beams

Rolled I-sections, are used for the design of beam and column. Because the rolled sections is the more economical type and is generally preferable to the built-up section even if the weight involved is greater.

a) Beam Design

The I section, ranging in depth from 80 to 600 mm, is now the most widely employed in multi-story buildings. Because of the thin web, such beam is very economical, while the parallel flanges facilitate the structural connections. Dimension and properties are taken from universal beam table.

Beam Section

Depth h_c= 467.4 mm

Width b= 192.8 mm

Web thickness t_{wc}= 11.4 mm

Flange thickness t_{fc}= 19.6 mm

The structural steel beam analysis and design are done using ETABS 2016 Ultimate 16.00.Then the section is check for strength and deflection (**Refer Appendix-A**).

b) Column Design

This is the most frequently used shape for column sections. It is very suitable for connections to beams in both directions, as all parts of the section are accessible for forming bolted joints. Dimension and properties are taken from universal beam table.

Column Section

Depth hc= 455.7 mm

Width b= 418.5 mm

Web thickness twc= 42 mm

Flange thickness tfc= 67.5 mm

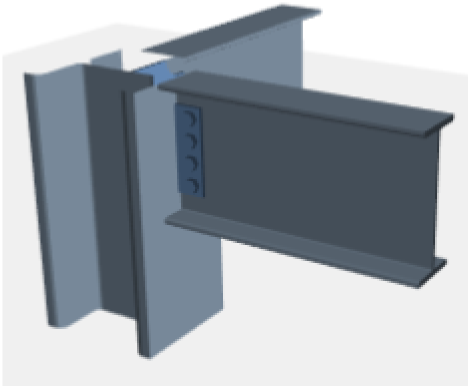
The structural steel column analysis and design are done using ETABS 2016 Ultimate 16.00.Then the section is check for strength (**Refer Appendix-B**).

6.4.2. Beam to Column Connection Design

At these connections the vertical loads are transmitted from the beams to columns. Such connections must:

- Provide a positive connection during erection,
- Be adjustable,
- Be capable of execution in a simple manner.

The structural steel connection analysis and design are done using ETABS 2016 Ultimate 16.00.Then base plate thickness, bolt and weld size are determined.



Connection Design: B37-CI

Story: Story1

Design Code: AISC 360-10

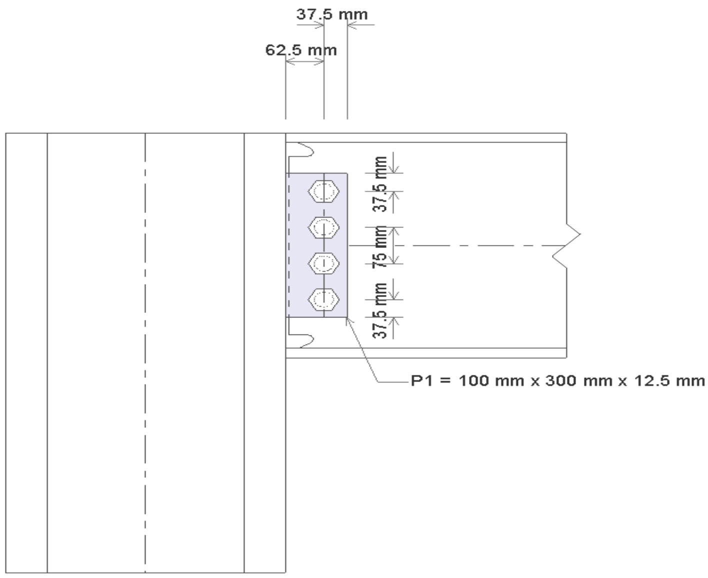


Figure 7. Beam-column moment major axis connection (ETABS, 2016)

Table 1.Summary of design results

	Design Check Type	D/C Ratio	Result	Reference

	Design Check Type	D/C Ratio	Result	Reference
1	Beam design flexural strength	0.112	Passed	Spec. Eq F13-1
2	Strength of bolt group	0.208	Passed	Pg 7-18 AISC manual
3	Shear yielding of web plate	0.128	Passed	J4-3
4	Shear rupture of web plate	0.246	Passed	J4-4
5	Block shear rupture strength of web plate	0.227	Passed	J4-5
6	Design strength of weld	0.173	Passed	J2-3
7	Web plate rupture strength at weld	0.062	Passed	Manual Eq 9-2
8	Shear yielding of beam web	0.088	Passed	J4-3
9	Shear rupture of beam web	0.116	Passed	J4-4
10	Block shear rupture strength of beam web	0.145	Passed	J4-5
11	Panel zone shear strength	0.219	Passed	AISC 13-Section 2.2.1
12	Local flange bending	0.291	Passed	AISC 13-Section 2.2.2
13	Local web yielding	0.376	Passed	AISC 13-Section 2.2.3
14	Web crippling	0.244	Passed	AISC 13-Section 2.2.3

Material Properties

Beam	S355	F_y	= 355 MPa	F_u	= 510 MPa
Column column	S355	F_y	= 355 MPa	F_u	= 510 MPa
Web Plate	A992Fy5	$F_{y=}$	344.74 MPa	$F_{u=}$	448.16 MPa

Geometric Properties

Beam	$t_{w=}$	11.4 mm	d	=467.4 mm	t_f	= 497.8 mm	b_f	= 192.8 mm
Column column	$t_{w=}$	= 42 mm	d	= 455.7 mm	t_f	= 67.5 mm	b_f	= 418.5 mm
Preferences	s	= 75 mm	L_{ev}	= 37.5 mm	L_{eh}	= 37.5 mm		

Bolts, Plate & Weld

Weld	Size, D(1/16)	= 100 mm		
Web Plate	Thickness, t	= 12.5 mm		
Bolt	Type	= A325-N	diameter, d_b	= 32 mm
Hole	Type	= STD	diameter, d_h	= 33.3 mm

6.4.3. Design of Prestressed Hollow Core Concrete Slab

The design of hollow core slabs is governed by the BS.8110:1997 part-1 code of practice for design and construction requirements for structural concrete. As with prestressed concrete members in general, hollow core slabs are checked for pre-stress transfer stresses, handling stresses, service load stresses deflections and design (ultimate) strength in shear and bending.

Slab Widths

Hollow core slabs are generally manufactured 1200mm wide, but other widths are available.

Slab Depths

Slab depths typically range from 100mm to 500mm.

Section Profiles

Section profiles of the precast element may vary in detail depending upon the manufacturer. Typical examples are overleaf.

Figure 8 Hollow core slab system, (**BS.8110:1997)**

Structural Performance

Table 1 gives general guidance on the performance characteristics of hollow core composite flooring and allowable characteristic live loads. This table is based upon a 75mm thick structural topping. Alternative depths may be used according to structural requirements. Spans are stated in linear meters with an allowance having been made for the self-weight of the unit plus a dead load of 0.25kN/m² for finishes.

Table 2 Typical maximum spans in meters

Imposed Load (kN/m^2)	Overall Depth (mm)						
	185	225	275	325	375	425	475
	Plank Depth (mm)						
	110	150	200	250	300	350	400
1.5	5.5	8.2	9.8	11.2	13.0	15.1	16.2
2.5	5.3	8.0	9.4	10.8	12.4	14.5	15.5
4.0	5.0	7.5	8.8	10.2	11.7	13.7	14.7
5.0	4.9	7.2	8.5	9.8	11.3	13.3	14.2
7.5	4.5	6.8	7.9	9.1	10.5	12.4	13.2

NOTE: Load/span capacity can vary between manufacturers. Consideration must also be given to the exposure conditions, location and size of openings, effects of camber, deflection and vibration.

From the table for imposed live load $4KN/m^2$ an plank width 250 mm the section that I propose 7.2m length and 1.20m width hollow core slab are safe.

Concrete C-25

Determine the loadings

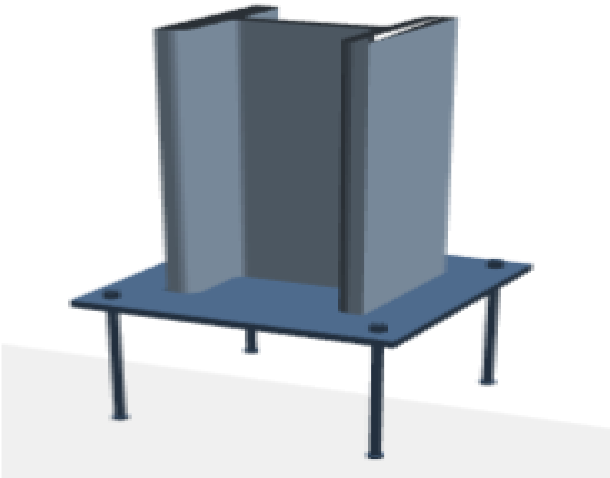
Assuming overall depth 'D' of the cross-section is 250mm, the other dimensions are

Calculated below.

- Height of voids ≤ 250 – 50 = 200mm…….Use dv =180mm
- Minimum flange thickness(tf) = $1.6\sqrt{D}$ = 25.30mm … Use 30mm for the top flange
- Also use a thickness of 30mm for the bottom flange.
- Width of web ≥ 30mm => Use tw = 30mm
- Width of hollow core slab b=1200mm

Column Base plates

The function of a column base plate is to distribute the column forces to the concrete foundation. In general a plain or slab base is used for pinned conditions or when there is very little tension between the plate and the concrete. In this project I use Pinned bases because they usually used in portal and in multi-story construction. The structural steel connection analysis and design are done using ETABS 2016 Ultimate 16.00.Then base plate thickness, bolt and weld size are determined.



Connection Design: C221-BP

Story: Story1

Design Code: AISC 360-10

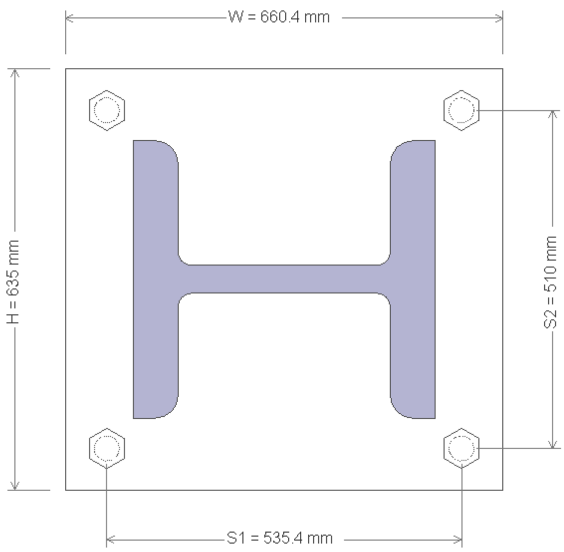


Figure 9. Column base plate connection (**BS.8110:1997**)

Table 3. Summary of results

	Design Check Type	D/C Ratio	Result	Reference
1	Concrete bearing capacity	0.787	Passed	
2	Base plate thickness	1.754	Passed	
3	Anchor rod strength	0.867	Passed	Design Guide 1, Secion3.2.1
4	Weld strength	0.219	Passed	J2-2, J2-3
5	Concrete pullout strength	0.481	Passed	
6	Concrete breakout strength	0.1	Passed	
7	Side-face blowout strength	0.052	Passed	

Material Properties

Column column	S355	F_y	= 355 MPa	F_u	= 510 MPa
Base Plate	A992Fy5	$F_{y=}$	344.74 MPa	$F_{u=}$	448.16 MPa

Geometric Properties

Column	$t_{w=}$	42 mm	d=	455.7 mm	$t_{f=}$	67.5 mm	$b_{f=}$	418.5 mm

Bolts, Plate & Weld

Base Plate	Width=	660.4 mm,	Height=	635 mm	Thickne=	29 mm

Pedestal

Dimension Width = 760.4mm Height =735 mm

Material Properties

Column column	S355	F_y	=	355 MPa	F_u	=	510 MPa
Base Plate	A992Fy5	F_y	=	344.74MPa	F_u	=	448.16MPa

Geometric Properties

Column column	t_w	=	42mm	d	=	455.7mm	t_f	=	67.5mm	b_f	=	418.5mm

Bolts, Plate & Weld

Base Plate Width =660.4mm Thickne s = 29mm

Height = 635mm

Pedestal

Dimension Width =760.4m

Height = 735mm

7. COMPARISON AND STRUCTURAL EVALUATION OF THE TWO SYSTEMS

7.1. Cost Comparison

One objective of this Project is also to investigate the relative advantages of the use of steel structural members with that of normal concrete construction, this section mainly deals the cost comparison of framed structures of the proposed two systems. The cost comparison is divided in to two components, the first is construction cost component, and the second is construction time component.

a) Construction Cost Component

In this section, the cost of construction (Material, Labor and equipment including profit and overhead costs), using the two systems, of the four-story building is calculated.

For Concrete

Table 4 Cost summary of the concrete low cost housing

DESCRIPTION	COST ESTEMATED
A. SUB-STRUCTURE	
Excavation and Earth work	546,944
Concrete work	1,197,676
Subtotal (A)	**1,744,620**
B.SUPER-STRUCTURE	
Concrete work	2,168,136
Subtotal (B)	**2,168,136**
Total (A+B)	**3,912,756**

For Steel System

Table 5. Cost summary of the steel-structure low cost housing

DESCRIPTION	**COST ESTEMATED**
A. SUB-STRUCTURE	
Excavation and Earth work	546,944
Concrete work	1,197,676
Subtotal (A)	**1,744,620**
B.SUPER-STRUCTURE	
Main structural steel works	5,134,010
Subtotal (B)	5,134,010
Total (A+B)	**6,878,630**

As can be seen from the two systems there is the difference

=6,878,630-3,912,756=2,965,874

b) Construction time component

It is known that the major advantage of using steel structural members for construction is the speed of construction, i.e. the use of this system save construction time .Since in the construction, time is money the use of steel structural system saves time and it gives opportunity to save money and to answer the vast demand of house shortage relative to that of concrete systems.

Concrete structural System

Note: FR C filling and Curing stands for Formwork, Reinforcement Concrete filling and Curing. In most construction activities, a number of crews are involved in particular activity to speed up the rate of construction, provided that, the contractor is capable of providing the necessary equipment and there is enough working area. For the purpose of comparison, in this project two crew are assumed to participate in each activity respectively.

Table 6. Rate of formwork, reinforcement and concrete

Main activity	Activities	Quantity	Output/day
FR C filling and curing	Formwork	m^2	125m2/day
	Reinforcement	kg	192kg/day
	Concrete	m^3	28.8m3/day

Table 7 Construction schedule for concrete system

PART	Main activity	Specific activity	Quantity	Output/day	(Days)
SUB-STRUCTURE	Excavation and Earth work	Site clearing	$776.08m^2$	$388.04m^2$/day	2
		Trench Excavation	$71.02m^3$	$35.51m^3$/day	2
		Pit Excavation	$828.56m^3$	$92.06m^3$/day	9
		Bacfill around masonry and footing columns	$344.40m^3$	$114.80m^3$/day	3
		Preparation of stone core	$194.02m^3$	$97.01m^3$/day	2
	Concrete	Forwork	$519m^2$	$129.75m^2$/day	4
		Reinforcement	11790kg	192kg/day	64
		Concrete fill and curing	$424m^3$	$85m^3$/day	5
	Masonry work	50cmthick hard trachytic masonry foundation	$74m^3$	$24.67m^3$/day	3
		10cm thick expansion joint to be filled with styrofoam	285m	95m/day	3
SUPER-STRUCTURE	Ground Floors Cols	FRC filling and curing			24
	1st Floor Beams	FRC filling and curing			21
	1st Floor Columns	FRC filling and curing			25
	2st Floor Beams	FRC filling and curing			22
	2st Floor Columns	FRC filling and curing			26
	3st Floor Beams	FRC filling and curing			23
	3st Floor Column	FRC filling and curing			27
	4st Floor Beams	FRC filling and curing			24
	4st Floor Columns	FRC filling and curing			28
	Total				**317**

Table 8 Construction schedule for steel-concrete system

PART	Main activity	Specific activity	Quantity	Output/day	Duration (Days)
SUB-STRUCTURE	Excavation and Earth work	Site clearing	776.08m^2	388.04m^2/day	2
		Trench Excavation	71.02m^3	35.51m^3/day	2
		Pit Excavation	828.56m^3	92.06m^3/day	9
		masonry and footing columns	344.40m^3	114.80m^3/day	3
		core	194.02m^3	97.01m^3/day	2
	Concrete	Forwork	519m^2	129.75m^2/day	4
		Reinforcement	6450kg	202kg/day	32
		curing	424m^3	85m^3/day	5
	Masonry work	50cmthick hard trachytic masonry foundation	74m^3	24.67m^3/day	3
		10cm thick expansion joint to be filled with styrofoam	265m	88m/day	3
SUPER-STRUCTURE	Ground and 1st Floor	Erection with connection	24pcs	6pcs/day	2
	1st Floor Beams	connection	230m	4pcs/day	10
	2stFloor Beams	Erection with connectio	40pcs	4pcs/day	10
	2nd and 3rd Floor Columns	Erection with connection	24pcs	6pcs/day	4
	3st Floor Beams	Erection with connection	40pcs	4pcs/day	10
	4st Floor Beams	Erection with connection	40pcs	4pcs/day	10
	4st Floor Columns	connection	24pcs	6pcs/day	4
	Total				**115**

As it can be clearly seen from the construction tables for the two systems, the construction time saved by using the steel structural system is, 202days=7months. The current rental cost of buildings, on average, is about 100 Birr/m2 - month. The owner of a building project will be benefited this sum, if the two systems are compared with time duration. Hence the saving gained from the speed of construction may be converted to financial value as:

As it can be clearly seen from the construction tables for the two systems, the construction time saved by using the steel structural system is, 202days=7months. The current rental cost of buildings, on average, is about 90 Birr/m2 - month

The owner of a building project will be benefited this sum, if the two systems are compared with time duration. Hence the saving gained from the speed of construction may be converted to financial value as:

Saving from construction time = (21.8m*35.6m) *(7months) *100birr/(m^2/month)

= **543,256 birr**

The total cost difference between the two systems is the sum of the difference of the two systems with regard to total construction cost component and from construction time component.

Total difference = 2,965,874-543,256

= **2,422,618 birr**

The total cost of the steel-framed structure is in excess of **2,422,618 birr** with respect to the concrete building.

7.2. Evaluation based of the management and efficiency of the construction

a) Production stage

In the production of steel structural members the environment is controlled and managed with the help of machineries, since the production of steel structural members inquire steel industries, so one can get exactly the required strength and dimensions of the members. Thus at the production stage steel structures are more manageable and efficient to that of concrete.

b) Analysis and Design stage

In the analysis and design of steel frame structures, one can use the exact weight of the members in the analysis and in the design part the strength of the section is used more than of 85% unlike concrete. So steel structural members are more manageable and efficient in analysis and design phase.

c) At Construction Level

At construction phase since most part of the steel structural members are arrived at the site almost processed; so the quality of the construction is hardly influenced by the site condition, so one can get the same quality of work regardless of the location of the site. In addition steel members are processed in machineries, so it is not possible to adjust the size or the dimensions of the members in addition it doesn’t allow chiseling to get the required shape unlike the concrete.
In addition to these,
shorter erection period permits an earlier recovery of capital.

d) At Functional Stage

- ✓ A very long service life, provided care is taken.
- ✓ The possibility of disassembling or replacing some steel members of a structure, for strengthening purposes

8. CONCLUSION AND RECOMMENDATIONS

8.1. Conclusions

In this project a steel and pre-stressed precast hollow core slab structure for low cost social housing building is proposed as alternative option for the buildings carried out these days. The proposed structural system for low cost social housing has given a good result with regard to the architectural view, floor to floor spacing, reduce cost of foundation, reduce cost of slab and leakage and construction time required for the completion of the construction. Though there is a disadvantage with regard to the construction cost component but it is compensated by simple foundation system and fast speed construction.

In cost estimation of the steel framed social housing, the most part the building cost is incurred on the main members and labor costs since the work of steel structures needs highly skilled and professional manpower. If the steel structural members demand in the Ethiopia is increased, so the newly steel industries get an opportunity to open and the existing steel industries expand their production with quality and quantity of production. In the long run it will enhance the capacity of the inborn industries in Ethiopia and reduces the hard currency spend for importing steel products.

In Ethiopia especially in the capital, Addis Ababa, the construction industry is increasing with alarming rate so the demand of construction materials is augmented from day to day, by virtue of this the cost of raw materials like cement, sand etc is increased. From this study and prevailing conditions in the country it can be concluded using the steel structure construction is logical that is to lessen the burden of the customary construction system and to see a better development in the construction industry.

Finally from using the steel and pre-stressed hollow concrete slab structural system for low cost social housing, it can be concluded that many small-scale enterprises develop from the new opportunity encounter; the users, different parties in the construction (from planning to the construction completion) and in cumulative effect the country get benefited.

8.2. Recommendation

In this project the steel and pre-stressed precast hollow core slab structure low cost social housing G+4 building is studied, the full building cost comparison is not accomplished. It is clear further and extensive research work needs to be done in order to accurately incorporate another alternatives and the total cost comparison among different options.

The following are among the areas of the steel structure which need further research.

1. Alternative new structure for high-rise buildings like G+8, G+20
2. Alternative steel structure with basement for parking purpose, steel slab system and the wall system.
3. This project is carried out based on low cost social-housing projects, it can be further studied in another commercial buildings.
4. Further extensive work is recommended to investigate the opportunity and benefits for the steel industries and stakeholders in the country.

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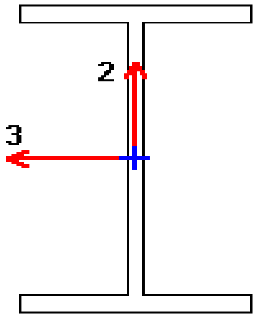
APPENDIX-A Beam design

ETABS 2016 Steel Frame Design

Euro code 3-2005 Steel Section Check (Strength Summary)



Element Details (Part 1 of 2)

Level	Element	Unique Name	Length (mm)	Location (mm)	Combo	Design Type	Element Type	Section
Story1	B37	293	7100	1145	DStlS1	Beam	DCH MRF	beam 1

Element Details (Part 2 of 2)

Classification	Rolled
Class 1	No

Design Parameters

National Annex	Combination Equation	Analysis Type	Reliability
CEN Default	Eq. 6.10	Method 2 (Annex B)	Class 2

Design Code Parameters

γ_{M0}	γ_{M1}	γ_{M2}	A_n / A_g	LLRF	PLLF	Stress ratio Limit
1	1	1.25	1	1	0.75	0.95

Section Properties

A (cm^2)	I_{yy} (cm^4)	i_{yy} (mm)	$W_{el,yy}$ (cm^3)	$A_{v,y}$ (cm^2)	$W_{pl,yy}$ (cm^3)	I_{yz} (cm^4)	I_t (cm^4)
68	7760.8	106.8	597.9	27.2	683.5	0	43.8

I_{zz} (cm^4)	i_{zz} (mm)	$W_{el,zz}$ (cm^3)	$A_{v,z}$ (cm^2)	$W_{pl,zz}$ (cm^3)	I_w (cm^6)	h (mm)
822.2	34.8	111.6	45.4	172.7	122295.1	259.6

A_{eff} (cm^2)	e_{Ny} (mm)	e_{Nz} (mm)	$W_{ef,yy}$ (cm^3)	$W_{ef,zz}$ (cm^3)
68	0	0	597.9	111.6

Material Properties

E (MPa)	f_y (MPa)	f_u (MPa)
210000	355	510

Stress Check Forces and Moments

Location (mm)	N_{Ed} (kN)	$M_{Ed,yy}$ (kN-m)	$M_{Ed,zz}$ (kN-m)	$V_{Ed,z}$ (kN)	$V_{Ed,y}$ (kN)	T_{Ed} (kN-m)
1145	3.1261	-7.1803	0.0035	-23.018	0.0014	0.0001

Demand/Capacity (D/C) Ratio 6.3.3(4)-6.62

D/C Ratio = $N_{Ed} /(\chi_z N_{Rk} /\gamma_{M1}) + k_{zy} [M_{y,Ed} /(\chi_{LT} M_{y,Rk} /\gamma_{M1})] + k_{zz} [M_{z,Ed} /(M_{z,Rk} /\gamma_{M1})]$
0.255 = 0 + 0.255 + 7.981E-05

Basic Factors

Buckling Mode	K Factor	L Factor	L Length (mm)	L_{cr} /i
Major (y-y)	1	0.948	6734.1	63.044
Major Braced	1	0.948	6734.1	63.044
Minor (z-z)	1	0.948	6734.1	193.695
Minor Braced	1	0.948	6734.1	193.695
LTB	1	0.948	6734.1	193.695

Axial Force Design

	N_{Ed} Force kN	$N_{c,Rd}$ Capacity kN	$N_{t,Rd}$ Capacity kN	$N_{byy,Rd}$ Major kN	$N_{bzz,Rd}$ Minor kN
Axial	3.1261	2414.6958	2414.6958	1711.6645	311.9772

$N_{pl,Rd}$ kN	$N_{u,Rd}$ kN	$N_{cr,T}$ kN	$N_{cr,TF}$ kN	A_n /A_g Unitless
2414.6958	2497.6797	3244.2215	3244.2215	1

Design Parameters for Axial Design

	Curve	A	N_{cr} (kN)	λ	Φ	χ	$N_{bd,Rd}$ (kN)
Major (y-y)	b	0.34	3547.0524	0.825	0.947	0.709	1711.6645
MajorB (y-y)	b	0.34	3547.0524	0.825	0.947	0.709	1711.6645
Minor (z-z)	c	0.49	375.7647	2.535	4.285	0.129	311.9772
MinorB (z-z)	c	0.49	375.7647	2.535	4.285	0.129	311.9772
Torsional TF	c	0.49	3244.2215	0.863	1.035	0.623	1504.0841

Moment Designs

	M_{Ed} Moment kN-m	$M_{Ed,span}$ Moment kN-m	$M_{c,Rd}$ Capacity kN-m	$M_{v,Rd}$ kN-m	$M_{n,Rd}$ kN-m	$M_{b,Rd}$ Capacity kN-m
Major (y-y)	-7.1803	-34.5198	242.6471	242.6471	242.6471	135.6197
Minor (z-z)	0.0035	0.0049	61.2997	61.2997	61.2997	

Moment Designs

	Section	Flange	Web	ε (Unitless)	α (Unitless)	ψ (Unitless)
Compactness	Class 1	Class 1	Class 1	0.814	0.498	-1.003

	Curve	α_{LT}	λ_{LT}	Φ_{LT}	χ_{LT}	C_1	M_{cr} (kN-m)
LTB	c	0.49	0.968	1.156	0.559	2.089	259.1352

	C_{my}	C_{mz}	C_{mLT}	k_{yy}	k_{yz}	k_{zy}	k_{zz}
Factors	1	1	1	1	0.6	1	1

Shear Design

	V_{Ed} Force (kN)	$V_{c,Rd}$ Capacity (kN)	T_{Ed} /Torsion (kN-m)	Stress Ratio	Status Check
Major (z)	23.018	557.1088	0.0001	0.041	OK
Minor (y)	0.0014	929.8673	0.0001	0	OK

Shear Design

	$V_{pl,Rd}$ (kN)	η (Unitless)	λ_W (Unitless)
Reduction	557.1088	1.2	0.329

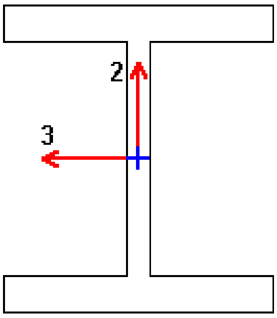
End Reaction Major Shear Forces

Left End Reaction (kN)	Load Combo	Right End Reaction (kN)	Load Combo
118.3348	DStlS18	118.4251	DStlS18

APPENDIX-B Column design

ETABS 2016 Steel Frame Design

Euro code 3-2005 Steel Section Check (Strength Summary)



Element Details (Part 1 of 2)

Level	Element	Unique Name	Length (mm)	Location (mm)	Combo	Design Type	Element Type	Section
Story2	C1	503	3000	1370.2	DStlS2	Column	DCH MRF	COLUMN

Element Details (Part 2 of 2)

Classification	Rolled
Class 1	No

Design Parameters

National Annex	Combination Equation	Analysis Type	Reliability
CEN Default	Eq. 6.10	Method 2 (Annex B)	Class 2

Design Code Parameters

γ_{M0}	γ_{M1}	γ_{M2}	A_n / A_g	LLRF	PLLF	Stress ratio Limit
1	1	1.25	1	0.706	0.75	0.95

Section Properties

A (cm^2)	I_{yy} (cm^4)	i_{yy} (mm)	$W_{el,yy}$ (cm^3)	$A_{v,y}$ (cm^2)	$W_{pl,yy}$ (cm^3)	I_{yz} (cm^4)	I_t (cm^4)
359.8	79041.8	148.2	4320.4	89.2	5105.5	0	2073.8

I_{zz} (cm^4)	i_{zz} (mm)	$W_{el,zz}$ (cm^3)	$A_{v,z}$ (cm^2)	$W_{pl,zz}$ (cm^3)	I_w (cm^6)	h (mm)
24740.6	82.9	1535.7	285.5	2349.2	6385592.1	365.9

A_{eff} (cm^2)	e_{Ny} (mm)	e_{Nz} (mm)	$W_{ef,yy}$ (cm^3)	$W_{ef,zz}$ (cm^3)
359.8	0	0	4320.4	1535.7

Material Properties

E (MPa)	f_y (MPa)	f_u (MPa)
210000	355	510

Stress Check Forces and Moments

Location (mm)	N_{Ed} (kN)	$M_{Ed,yy}$ (kN-m)	$M_{Ed,zz}$ (kN-m)	$V_{Ed,z}$ (kN)	$V_{Ed,y}$ (kN)	T_{Ed} (kN-m)
1370.2	-559.9409	2.0049	2.1536	-16.717	-8.1509	-0.0028

Demand/Capacity (D/C) Ratio 6.3.3(4)-6.61

D/C Ratio = $N_{Ed} /(\chi_y N_{Rk} /\gamma_{M1}) + k_{yy} [M_{y,Ed} /(\chi_{LT} M_{y,Rk} /\gamma_{M1})] + k_{yz} [M_{z,Ed} /(M_{z,Rk} /\gamma_{M1})]$
0.16 = 0.15 + 0.006 + 0.004

Basic Factors

Buckling Mode	K Factor	L Factor	L Length (mm)	L_{cr} /i
Major (y-y)	6.509	0.913	2740.4	120.345
Major Braced	0.992	0.913	2740.4	18.343
Minor (z-z)	2.858	0.913	2740.4	94.452
Minor Braced	0.958	0.913	2740.4	31.668
LTB	2.858	0.913	2740.4	94.452

Axial Force Design

	N_{Ed} Force kN	$N_{c,Rd}$ Capacity kN	$N_{t,Rd}$ Capacity kN	$N_{byy,Rd}$ Major kN	$N_{bzz,Rd}$ Minor kN
Axial	-559.9409	12772.3888	12772.3888	3722.1027	4623.808

$N_{pl,Rd}$ kN	$N_{u,Rd}$ kN	$N_{cr,T}$ kN	$N_{cr,TF}$ kN	A_n /A_g Unitless
12772.3888	13211.3272	65546.1773	65546.1773	1

Design Parameters for Axial Design

	Curve	α	N_{cr} (kN)	λ	Φ	χ	$N_{bd,Rd}$ (kN)
Major (y-y)	c	0.49	5148.8069	1.575	2.077	0.291	3722.1027
MajorB (y-y)	c	0.49	221634.0821	0.24	0.539	0.98	3722.1027
Minor (z-z)	d	0.76	8358.7986	1.236	1.658	0.362	4623.808
MinorB (z-z)	d	0.76	74355.6281	0.414	0.667	0.84	4623.808
Torsional TF	d	0.76	65546.1773	0.441	0.689	0.821	10482.7576

Moment Designs

	M_{Ed} Moment kN-m	$M_{Ed,span}$ Moment kN-m	$M_{c,Rd}$ Capacity kN-m	$M_{v,Rd}$ kN-m	$M_{n,Rd}$ kN-m	$M_{b,Rd}$ Capacity kN-m
Major (y-y)	2.0049	24.9106	1812.4678	1812.4678	1812.4678	1615.8677
Minor (z-z)	2.1536	13.322	833.9825	833.9825	833.9825	

Moment Designs

	Section	Flange	Web	ε (Unitless)	α (Unitless)	ψ (Unitless)
Compactness	Class 1	Class 1	Class 1	0.814	0.606	-0.912

	Curve	α_{LT}	λ_{LT}	Φ_{LT}	χ_{LT}	C_1	M_{cr} (kN-m)
LTB	c	0.49	0.411	0.636	0.892	2.7	10733.696

	C_{my}	C_{mz}	C_{mLT}	k_{yy}	k_{yz}	k_{zy}	k_{zz}
Factors	0.4	0.4	0.4	0.401	0.243	0.986	0.405

Shear Design

	V_{Ed} Force (kN)	$V_{c,Rd}$ Capacity (kN)	T_{Ed} /Torsion (kN-m)	Stress Ratio	Status Check
Major (z)	16.717	1827.82	-0.0028	0.009	OK
Minor (y)	8.1509	5850.9553	-0.0028	0.001	OK

Shear Design

	$V_{pl,Rd}$ (kN)	η (Unitless)	λ_W (Unitless)
Reduction	1827.82	1.2	0.147

Joint Design

Continuity Plate Area (cm²)	Load Combo	Doubler (mm)	Load Combo
5.5	DStlS18	0	DStlS18

Beam/Column Capacity Ratios

Major Ratio	Load Combo	Minor Ratio	Load Combo
0.109	DStlS18	0.244	DStlS18

APPENDIX-C Cost-estimation of Building using Concrete and steel

A) For Concrete

ITEM	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
	A. SUB- STRUCTURE				
	1. EXCAVATION & EARTH WORK				
1.1	Site clearing to a depthof 20cm top soil	m2	787.4	10	7,874
1.2	Bulk excavation to reduce level to an average depth				
	of 150cm .	m^3	1241	46	57,086
1.3	Excavation for footing foundation in ordinary soil to				
	a depth not exceeding 1.5m starting from				
	reduced level	m^3	284	88	24,992
1.4	Trench foundation excavation in ordinary soil				
	not exceeding 1.5m starting from reduced level	m^3	209	88	18,392
1.5	Back fill around foundation withfrom site				
	material from out side & well ram in layers not				
	exceeding 20cm thick.	m^3	196	45	8,820
1.6	Ditto selected borrowed material from out side				
	under hard core	m^3	313	211	66,043
1.7	Fill behind retaining wall with deferent gravel size	m^3	254	483	122,682
1.8	Cart away surplus excavated material to an				
	appropriate tip	m^3	1734	63	109,242
1.9	25cm thick basaltic or equivalent stone hard				
	core well rolled consolidated and blinded with				
	crushed stones.	m^2	625	206	128,750
	TOTAL TO SUMMARY………………….	**BIRR**			**543,881**
	2. CONCRETE WORK				
2.1	5cm thick lean concrete class C-7, with minimum				
	cement content of 150kg /m3 under foundation	m^2	126.2	88	11,109
2.3	In footings	m^3	79.14	2,750	217,635
2.5	In retaining wall	m^3	101.4	2,750	278,850
2.7	In Grade beams	m^3	34.5	2,750	94,908
	Reinforcement steel bar according to St.drawing				
	price includes cutting, bending, placing in				
	position and tying wires.				
2.15	Dia 20 mm deformed bar	kg	4885	36	175,848
2.16	Dia 16 mm deformed bar	kg	3856	36	138,833
2.20	Dia 10 mm deformed bar	kg	4381	36	157,705
2.17	Dia 8 mm deformed bar	kg	2982	36	107,352
2.20	Expansion joint 10x2cm chip wood between				
	G.beam and slab painted with bitumen asphalt.	m	426	30	12,780
	TOTAL TO SUMMARY………………….	**BIRR**			**1,195,020**

	B. SUPER - STRUCTURE				
	1.Concrete frame				
1.1	RCC class-25,360kgs cement/m2 filled into formwork and vibrated around reinforcement bars and form workseparately.				
	a)In elevation column	m3	45	2,750	123,750
	b)In floor beams	m3	68	2,750	187,000
	c)In water tawer slab	m3	3	2,750	8,250
	d)In stair case	m3	12	2,750	33,000
	e)In water tawers beams	m3	1	2,750	2,750
	f)In top tie beams	m3	16	2,750	44,000
1.2	Ribbed slab for (1-4th) floor made of 6mm concrete slab 8x120mm one way precast concreye beam or girder with c/cspacing 625mm ,220x515mm average hollow concrete reimed block all according to the detail structural drawings	m3	87	2,750	239,250
1.3	Provide cut and fix in position sawn zigba wood formworkwich ever appropriate				-
	a)In elevation column	m2	405	320	129,600
	b)In floor beams	m2	718	320	229,760
	c)In water tawer slab	m2	21	320	6,720
	TOTAL TO SUMMARY…………………..	**BIRR**			**2,168,136**
	02 . ROOFING				
2.1	Supply and Fix Galvanized Ribbed sheet & Accessories				
	(Roof cover measured in actual projection				
	and purlin measured separately)				
	EGA 300,0.4mm thick	m2	534	327	174,618
2.2	Galvanized plain steel sheet & accessories				-
	Flushing				-
	0.4 mm thick, girth33cm	ml	72	260	18,720
3.2	7cm average thick light weight concrete over concrete				-
	slab with 2% slope to wards down pipe .	m^2	123	210	25,830
	TOTAL TO SUMMARY…………………..	**BIRR**			**219,168**
	03.ROOF STEEL STRUCTURE				
	Supply ,make, and mount RHS steel truss all according				
	to structural drawing price includes all				
	necessary work for secure installation & two				
	RHS TRUSS				
3.1	Size 80x80x3mm	Kg	4419	58	256,207.24
3.2	Size 60x60x2.5mm	Kg	1125	58	65,229.57
	Purlin lattice type				-
3.3	Size 40x40x3mm	Kg	3572	58	207,111.12
3.4	Diameter 14mm	Kg	1477	58	85,639.17
	Plate				-
3.5	8 mm thick	Kg	160	58	9,277.09
	Angle ties				-
3.6	Size-50x50x4mm L=120mm	No	220	32	7,040.00
	Bolts				-
3.7	M16	No	44	25	1,100.00
3.8	M12	No	220	20	4,400.00
	TOTAL TO SUMMARY…………………..	**BIRR**			**636,004**
	4.WATER PROOFING WORK				
4.1	Water proofing for baement Retaining wall				
	Apply cementicious damp proofig material for wet area	m^2	507	1049.00	531,843
	all associated works including back side birick wall and Perforated pipeworks				
4.2	Bitumen with 4mm thick sand finished or equivalent				
	water proofing material tor top roof slab	m^2	123	340	41,820
	TOTAL TO SUMMARY…………………..	**BIRR**			**573,663**
	GRAND TOTAL TO SUMMARY…………………..	**BIRR**			**5,335,872**

A) For Steel Frame

ITEM	DESCRIPTION	UNIT	QTY	RATE	AMOUNT
	A. SUB- STRUCTURE				
	1. EXCAVATION & EARTH WORK				
1.1	Site clearing to a depthof 20cm top soil	m2	787	10	7,870
1.2	Bulk excavation to reduce level to an average depth				
	of 150cm .	m^3	1241	46	57,086
1.3	Excavation for footing foundation in ordinary soil to				
	a depth not exceeding 1.5m starting from				
	reduced level	m^3	284	88	24,992
1.4	Trench foundation excavation in ordinary soil				
	not exceeding 1.5m starting from reduced level	m^3	209	88	18,392
1.5	Back fill around foundation withfrom site				
	material from out side & well ram in layers not				
	exceeding 20cm thick.	m^3	196	45	8,820
1.6	Ditto selected borrowed material from out side				
	under hard core	m^3	313	221	69,173
1.7	Fill behind retaining wall with deferent gravel size	m^3	254	483	122,682
1.8	Cart away surplus excavated material to an				
	appropriate tip	m^3	1733	63	109,179
1.9	25cm thick basaltic or equivalent stone hard				
	core well rolled consolidated and blinded with				
	crushed stones.	m^2	625	206	128,750
	TOTAL TO SUMMARY…………………..	**BIRR**			**546,944**
	2. CONCRETE WORK				
2.1	5cm thick lean concrete class C-7, with minimum				
	cement content of 150kg /m3 under foundation	m^2	126.24	88	11,109
2.3	In footings	m^3	79.14	2,750	217,635
2.5	In retaining wall	m^3	101.4	2,750	278,850
2.7	In Grade beams	m^3	34.5	2,750	94,875
	Reinforcement steel bar according to St.drawing				
	price includes cutting, bending, placing in				
	position and tying wires.				
2.15	Dia 20 mm deformed bar	kg	4885	31	151,425
2.16	Dia 16 mm deformed bar	kg	3856	31	119,550
2.20	Dia 10 mm deformed bar	kg	4381	31	135,802
2.17	Dia 8 mm deformed bar	kg	2982	31	92,450
2.18	Column Base Plate, 660.4x635, Thick 29mm	Pc	26	3,200	83,200
2.20	Expansion joint 10x2cm chip wood between				
	G.beam and slab painted with bitumen asphalt.	m	426	30	12,780
	TOTAL TO SUMMARY…………………..	**BIRR**			**1,197,676**
	B. SUPER - STRUCTURE				

	B. SUPER - STRUCTURE				
	1.STEEL FRAME				
1.1	Supply and fix Hot Rolled Structural steel beam as per the drawing				
	S355 Fy = 355 MPa Fu = 510 Mpa				
	Beam Section				
	Depth hc= 467.4 mm				
	Width b= 192.8 mm				
	Web thickness twc= 11.4 mm				
	Flange thickness tfc= 19.6 mm	m	970	1,900	1,843,760
1.2	Supply and Fix Hot Roled Strctural steel Column,for Middle columns				
	S355 Fy= 355 MPa , Fu = 510 MPa				
	Column Section				
	Depth hc= 436.6 mm				
	Width b= 412.5 mm				
	Web thickness twc= 35 mm				
	Flange thickness tfc= 58 mm	m	200	4,300	860,000
1.3	Supply and Fix Hot Roled Strctural steel Column, for Edge columns				
	S355 Fy= 355 MPa , Fu = 510 MPa				
	Column Section				
	Depth hc= 455.7 mm				
	Width b= 418.5 mm				
	Web thickness twc= 42 mm				
	Flange thickness tfc= 67.5 mm	m	135	6,436	868,860
1.3	Prestressed Hollow Core Concrete Slab				
	Width of hollow core slab b=1200mm				
	overall depth 'D' of the cross-section is 250mm				
	30mm for the top flange				
	Also a thickness of 30mm for the bottom flange.				
	Width of web ,tw = 30mm	m^2	2623	466	1,222,318
1.4	Supply and fix steel composite sections for Stair case				
	as per the drawing ,the rate shouldinclude all incidental works accociated	ml	38	6,720	252,672
1.5	Double Plates ,100*300*12.5mm	No	120	400	48,000
1.6	Bolts,Diameter 32mm,length 600mm	No	480	80	38,400
	TOTAL TO SUMMARY………………….	**BIRR**			**5,134,010**

	02 . ROOFING				
2.1	Supply and Fix Galvanized Ribbed sheet & Accessories				
	(Roof cover measured in actual projection				
	and purlin measured separately)				
	EGA 300,0.4mm thick	m2	534	327	174,618
2.2	Galvanized plain steel sheet & accessories				-
	Flushing				-
	0.4 mm thick, girth33cm	ml	72	260	18,720
					-
3.2	7cm average thick light weight concrete over concrete				-
	slab with 2% slope to wards down pipe .	m^2	123	210	25,830
3.3	3cm thick cement screed over light weight concrete .	m^2	123	145	17,835
	TOTAL TO SUMMARY………………….	**BIRR**			**237,003**
	03.ROOF STEEL STRUCTURE				
	Supply ,make, and mount RHS steel truss all according				
	to structural drawing price includes all				
	necessary work for secure installation & two				
	coats of anti rust paint				
	RHS TRUSS				
3.1	Size 80x80x3mm	Kg	4418.75	58	
3.2	Size 60x60x2.5mm	Kg	1125	58	65,229.57
					-
	Purlin lattice type				-
3.3	Size 40x40x3mm	Kg	3572	58	
3.4	Diameter 14mm	Kg	1477	58	85,639.17
					-
	Plate				-
3.5	8 mm thick	Kg	160	58	9,277.09
					-
	Angle ties				-
3.6	Size-50x50x4mm L=120mm	No	220	32	7,040.00
	Bolts				-
3.7	M16	No	44	25	1,100.00
3.8	M12	No	220	20	4,400.00
	TOTAL TO SUMMARY………………….	**BIRR**			**172,686**
	4.WATER PROOFING WORK				
	Apply cementicious damp proofig material for wet area	m^2	507	1049.00	531,843
	all associated works including back side birick wall and Perforated pipeworks				
4.2	Bitumen with 4mm thick sand finished or equivalent				
	water proofing material tor top roof slab	m^2	123	340	41,820
	TOTAL TO SUMMARY………………….	**BIRR**			**531,843**
	GRAND TOTAL TO SUMMARY………………….	**BIRR**			**7,820,162**

APPENDIX-D Column detail